Shaping future cities

Emine Mine Thompson and Paul Greenhalgh explain how NewcastleGateshead is integrating data sets in its quest to engage citizens in a smart city model

According to OECD forecasts, by 2050 70% of the world's nine billion population will be living in cities. Cities are already suffering from immense demand for resources. The convergence of GIS, building information models (BIM) and 3D city modelling, as well as other geospatial data sets and technologies, offers enormous potential to help address these demands.

A virtual city model can become a smart model when it has been enhanced with data gathered by local authorities, citizens and organisations which serve as a cross-disciplinary platform and communication medium for urban planning, economic development and management.. While there has been a proliferation of 3D city models, due to increasing availability of 'off the shelf' geometric data, there are few examples of unified, information rich digital city models that integrate with existing GIS and BIM data.

Local governments across Europe are preparing for the INSPIRE directive, which will require cities to have spatial data infrastructure by 2019. This will enable the sharing of environmental spatial information among public sector organisations and facilitate public access. Meanwhile, the UK government is committed to 3D BIM on its projects by 2016. These top-down enforcements are making local authorities and businesses look into gathering and using data in a different way.

One approach is to integrate data into a 3D city model. Virtual NewcastleGateshead (VNG) is a joint venture between Northumbria University, Newcastle City Council and Gateshead Metropolitan Borough Council, to create a 3D digital model of the urban core areas of Newcastle and Gateshead. From a preliminary coverage of 8.5km^2 in 2008 it has now expanded to cover 100km^2 of Newcastle, Gateshead and North Tyneside. The VNG team is exploring extending the coverage to Sunderland, Durham, Teesside and Northumberland -Virtual NorthEast.

Its experience has demonstrated that the successful integration of 3D geometric data, with existing GIS datasets created by local authorities, is best tackled by multidisciplinary teams embracing new tools, methodologies and technologies. This overcame the challenges presented by different software and hardware systems and different technical capacities in converting data within a unified data rich city model.

Integrating data

In any urban planning process, semantic and/or graphical data is the key element. GIS sustains spatial information and offers methods of analysing it, helping users to gain facts regarding geographic surroundings.
The first data rich GIS representations, in the form of 2D grayscale maps, emerged in the 1960s Rapid advancement in hardware and software led to the emergence of 2D, 2.5D and 3D GIS, however, the integration of GIS with urban modelling did not occur until the late 1980s.

While GIS visualisation is widely employed, the modelling capability of GIS is relatively under-used. With increasing supply and usability of spatial data, GIS has great potential to model the urban components easily and accurately within systems.

Although GIS and computer aided design (CAD) can represent the same real-world objects, they were originally created for different domains. CAD software was designed for relatively small geometric models with a focus on visualisation, GIS software, especially 2D GIS, was designed to deal with geospatial models covering relatively vast areas with spatial analytical functions.

Despite increasing convergence of 3D GIS and CAD software, particularly in respect of functionality, there are still application issues, such as querying 3D geo-objects, 3D structuring, manipulation and analysis, that need to be overcome to achieve effective integration.

Parallel to the development of off-the-shelf, low cost 3D city models, two data models, the City Geography Markup Language (CityGML) and the Keyhole Markup Language evolved as Open GIS standards, which can be used for storage and exchange of 3D city models.

The purpose of CityGML was to reach a definition and understanding of the basic entities, attributes, and relations within a 3D city model.
By providing a core model with entities relevant to many disciplines the city model can become a central information hub. Information exchange between different disciplines can be aligned with the objects of the city model. CityGML does not only represent the graphical appearance of city models but also addresses the representation of the semantic and thematic properties, taxonomies and aggregations of digital terrain models, sites, vegetation, water bodies, transportation facilities, city furniture.

The underlying model differentiates five consecutive levels of detail (LOD) on a scale of LOD0 to LOD4, where objects become more detailed with increasing LOD regarding both geometry and thematic differentiation.

Putting into practice

Both Newcastle and Gateshead councils have their own 2D GIS where various data sets are collected and used. A GIS Integration group was established in 2010 that aimed to:

- understand the needs and requirements of the main stakeholders and identify a set of criteria to align with these goals
- identify tools and technologies oriented towards the integration of GIS data into digital city models
- screen potential tools and technologies with required functional requirements and performance characteristics
- recommend a preferred solution, including financial implications, and implementation strategy.

Although CAD and GIS staffing and hardware varied between the two authorities, both used the same ArcGIS software and varying levels of other software, for example CAD, 3DsMax, SketchUP, BIM tools, LandExplorer.

They identified similar requirements for GIS integration in terms of coverage, data format, LODs, geo-referencing existing data, management of updates and changes to the model, version control, change register, INSPIRE compliant metadata tags and user requirements with regards to tools and skill sets.

A GIS cycle of data authoring-storage and publish-use was designed to accommodate these requirements (see Figure 1). From a business point of view, the cycle also represents the roles, responsibilities and skill sets of the users, whether they are 3D city modellers, GIS analysts, data distributors and publishers, consumers who use the end product and the tools needed to run this cycle.
Application specific skill sets are required for authoring and publishing points of the cycle, but for end users data can be accessed by lightweight viewers.

Figure 1 GIS-Cycle

One of the key requirements of the VNG project was to integrate the GIS datasets of both authorities in one 3D model to enable advanced spatial analyses and 3D visualisations (see Figure 2).

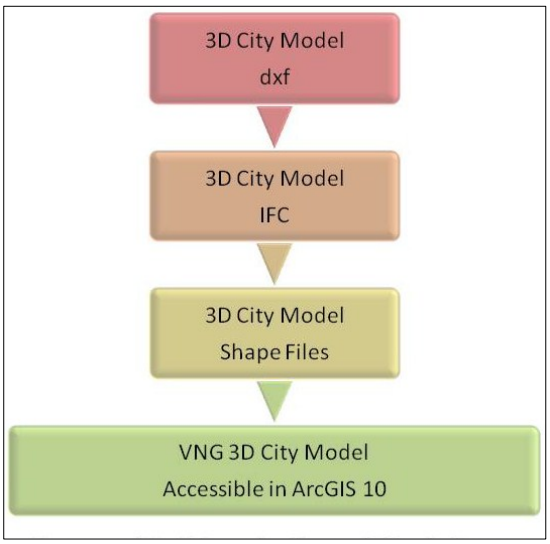

Figure 2 Conversion Process

Smart outcome

The collaboration between academia and local government has influenced how the two local planning authorities approach urban planning, for example the emerging NewcastleGateshead Core Strategy and Urban Core Plan.

Bringing together three large organisations, with differing hardware capabilities and software skills and technological applications, creates challenges that need to be handled patiently and carefully.

Most issues arising from 3D GIS integration were technological in nature, such as network compatibility, data format and conversion, software selection and inter-operability. These are universal problems that can be overcome through improvements on open formats, network standards and data management.

An emerging issue is the need to manage, store, disseminate and use 3D information for the whole built environment, from a macro to a micro scale, by connecting GIS with BIM technology. Data, whether it is in 2D or 3D format or in micro or macro level with different ownerships, needs to be joined together to generate an information rich city model.

There are many aspects of data such as origin, acquisition, and ownership issues that require further critical exploration in seeking to underpin a more sustainable 3D model. But sharing the core data and predictions and simulations with the users and the stakeholders are important aspects of what makes the city 'smart' by providing best available services to its citizens.

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Web links:

VNG: http://virtualng.northumbria.ac.uk/
BIM Academy: http://collab.northumbria.ac.uk/bim2/
3D city models across the world visit: www.virtualcitymodels.co.uk

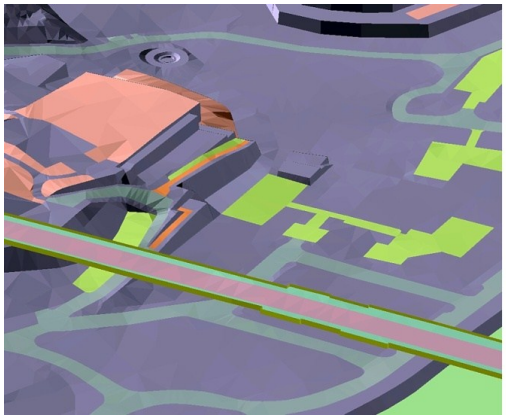

Figure 3: VNG Terrain in ArcGIS 10

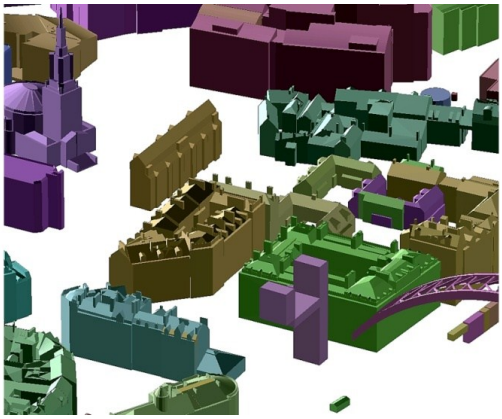

Figure 4: VNG Buildings in ArcGIS 10

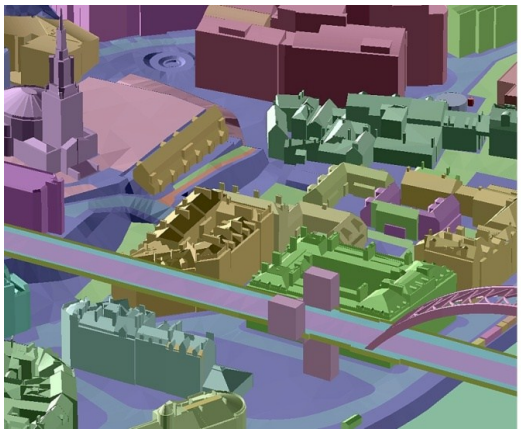

Figure 4: Terrain and Buildings together

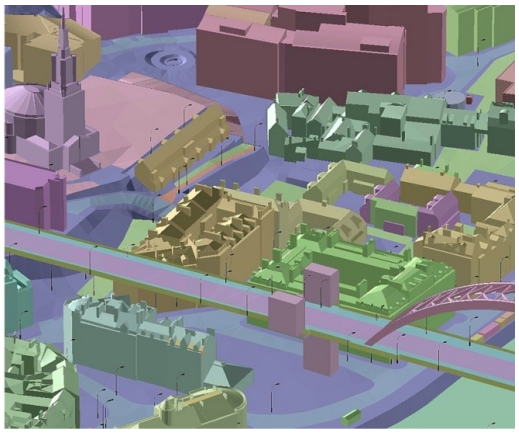

Figure 6: Lighting columns data in VNG

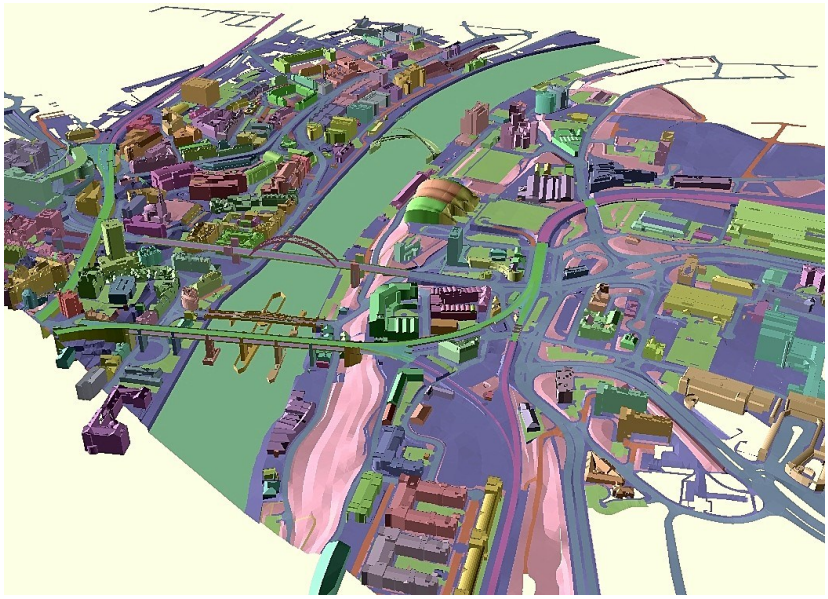

Figure 7 VNG in ArcGIS 10